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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent application of
Wolfgang KRAMER
Corres. to PCT/EP2004/013832
For: HEAT EXCHANGER

VERIFICATION OF TRANSLATION

Commissioner for Patents
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Sir:

I, Susan ANTHONY BA, ACIS,

Director of RWS Group Ltd, of Europa House, Marsham Way, Gerrards Cross, Buckinghamshire, England declare:

That the translator responsible for the attached translation is familiar with both the German and the English language, and that, to the best of RWS Group Ltd knowledge and belief, the attached English translation of International Application No. PCT/EP2004/013832 is a true, faithful and exact translation of the corresponding German language paper.

I further declare that all the statements made in this declaration of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful, false statements may jeopardize the validity of legal decisions of any nature based on them.

June 21, 2006

Date

Name: S. ANTHONY
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Heat exchanger

The invention relates to a heat exchanger, such as, in particular, a flat tube heat exchanger, and to a fin, such as, in particular, a corrugated fin, for example for a flat tube heat exchanger, in particular for a coolant or charge-air cooler or condensers or evaporators for motor vehicles according to the precharacterizing clause of patent claim 1.

Heat exchangers of this type have been disclosed by EP 0 547 309 B1 by the applicant.

Corrugated fins and flat tubes form a soldered cooling system in which a medium to be cooled, for example a coolant or charge air, flows through the flat tubes and a cooling medium, for example ambient air, flows over the corrugated fins. Soldered cooling systems of this type are used for coolant coolers for cooling an internal combustion engine or as charge-air coolers for cooling the compressed intake air of internal combustion engines in motor vehicles. Heating elements or condensers or evaporators, for example, are also of similar construction. Fins can also be used in mechanically joined heat exchangers in which the fins and the tubes of the heat exchangers are connected mechanically to one another.

Development tends to go in the direction of higher pressures for the medium to be cooled, in particular in the coolant circuit, with the flat tubes being of extremely slender design on account of the lower

pressure drop on the air side, and therefore being extremely unstable to increased internal pressure. The flat tubes therefore tend to "swell", i.e. to form a bulge, under internal pressurization. This bulge can be counteracted from the inside and outside: in the interior of the flat tube, use is made of soldered turbulence inserts which act as tie rods, and corrugated fins exert a supporting effect on the flat tubes from the outside. The flat tubes are provided with gills to improve the heat transfer, which has disadvantages in terms of strength. The corrugated fins therefore tend to buckle at higher internal pressure loading of the flat tubes.

It has therefore been proposed in US-A 4,693,307 to mold a stiffening bead into the center of a gilled panel, i.e. an individual double gill which is designed in the shape of a roof and at the same brings about a deflection of the flow.

EP 0 547 309 B1 by the applicant has disclosed a corrugated fin for flat tubes, in which a stiffening bead is arranged between two gilled panels and in the center of the flat tube, i.e. the point at which the greatest buckling stress occurs for the corrugated fin. However, only a spot-type stiffening of the corrugated fin is achieved with this, which is no longer adequate if the stress increases as a consequence of increased internal pressure.

It is the object of the present invention to improve a corrugated fin of the type mentioned at the beginning with regard to its supporting effect without its thermodynamic properties, such as heat transfer and pressure drop, being adversely affected.

This object is achieved by the features of patent claim 1 and of claim 11. According to the invention,

the stiffening means are integrated in the gills, i.e. in principle all of the gills of the corrugated fin contribute to the supporting effect. The flat tubes are therefore supported over their entire length by a stiffened corrugated fin. Each individual gill advantageously has a buckle-proof profile with which the entire corrugated fin obtains increased security against buckling.

According to an advantageous refinement of the invention, the profile of each gill has an S-shaped cross section. This achieves the advantage of a greater moment of resistance to buckling without the pressure drop on the air side over the corrugated fin increasing significantly - in contrast, even a lower pressure drop is to be expected. The gills of S-shaped design in cross section therefore have, in contrast to the prior art, a variable gill angle which initially rises from a very low value to a maximum value in the center of the gill length and then goes back again to a minimum value. A "gentle" deflection of the air flow is therefore achieved without - as in the prior art - loss-affected eddies occurring at the incident-flow edge and flow-off edge of the gills. An unexpected combination effect turns out to be advantageous by the buckling resistance of the gills being increased and their pressure drop being reduced at the same time.

According to a further advantageous refinement of the invention, the cross section of the gills is bent twice and has an approximately Z-shaped profile, i.e. the gill bent in accordance with the invention has three gill angles, with the gill angle jumping at the first buckling point from a low to a high value and jumping again at the second buckling point to the low value. In comparison to the S-shape, the Z-shape therefore has a discontinuous profile of the gill angle over the gill length, which affords simplification in terms of

manufacturing. Moreover, the advantage is also achieved here of increased buckling resistance, associated with a reduced pressure drop.

According to further advantageous refinements of the invention, advantageous angle dimensions are indicated both for the S-shaped and for the Z-shaped cross section of the gill. In this case, in particular the low incident-flow angle and flow-off angle are advantageous because, as a result - as already mentioned - a formation of eddies behind the incident-flow edge and flow-off edge is avoided. At the same time, the heat transfer capacity of the corrugated fin is not made worse, since, as before, a new starting of the thermal boundary layer takes place at each incident-flow edge of a gill. This mechanism is responsible for a large part of the heat transmission. Finally, the advantage is also achieved thereby that the entire heat exchanger is improved in respect of its efficiency.

Exemplary embodiments of the invention are illustrated in the drawing and are described in more detail below. In the drawing

Figure 1 shows a corrugated fin with gills according to the prior art in a view from the front,

Figure 2 shows the corrugated fin according to the prior art in a plan view,

Figure 3 shows a section through the corrugated fin according to Figure 2 along the line III-III,

Figure 4 shows the corrugated fin according to the prior art and its loading,

Figure 5 shows a corrugated fin according to the invention with an S-shaped cross section,

Figure 6 shows a corrugated fin according to the invention with a cross section with a double bend,

Figure 7 shows a detail X from Figure 5, and
Figure 8 shows a detail Y from Figure 6.

Figure 1 shows a corrugated fin 1 with gills 2 as seen in the air flow direction. The corrugated fin 2 is part of a cooling system (not illustrated at all), comprising corrugated fins and flat tubes 3 which are indicated by dashed lines. The corrugated fins are arranged in each case between two tubes. The tubes are, for their part, connected in a fluid-tight manner at their end regions to header boxes. The tubes are typically inserted into openings in the header box and are connected in a fluid-tight manner to them. The tubes are preferably pushed into a tube plate with openings and are connected in a sealed manner, so that the fluid can pass from one header box to the other header box by the fluid connections within the tubes. The corrugated fin 1 and the flat tubes 3 are preferably in each case composed of an aluminum material and are soldered to one another. However, in other variant embodiments, use can also be made of other materials, such as, for example, steel in particular for exhaust gas heat exchangers, or copper or other alloys.

Figure 2 shows the corrugated fin 1 in a plan view, with the air flow direction being illustrated by an arrow L. The gills 2 form two gilled panels with front gills 2a and rear gills 2b.

Figure 3 shows a section along the line III-III and the oppositely directed gill angles $\alpha 1$ and $\alpha 2$ of the front gills 2a and of the rear gills 2b, respectively.

Figure 4 shows the corrugated fin 1 according to the prior art and its loading by the flat tubes (not illustrated here) when the latter are subjected to internal pressure. The loading of the corrugated fin 1

is illustrated by arrows P1, P2 which act in each case on a fin bend 1a, 1b. This results in a pressure loading of the fin sections between the fin bend 1a, 1b, i.e. also to a pressure loading of the gills 2, which are also therefore subject to a buckling load. Owing to the rectangular cross section of the known gills 2, a relatively low buckling load is produced here permitting the corrugated fin 1 to buckle as per the prior art (cf. Dubbel, Taschenbuch für den Maschinenbau [Handbook for machine construction], 20th edition, C 43).

Figure 5 shows a corrugated fin 5 according to the invention with front gills 6a and rear gills 6b which have an S-shaped cross section. The S-shaped cross section is characterized by a continuously variable gill angle from the entry to the exit of the air flow. An enlarged cross section is illustrated as detail X in Figure 7 and is described there in more detail.

Figure 6 shows a further embodiment of the invention, namely a corrugated fin 7 with front gills 8a and rear gills 8b which are in each case bent twice, i.e. have a double bend. The gill angle changes discontinuously in the case of this double bend gill 8a, 8b, i.e. changes in each case at the buckling point. An enlarged illustration is illustrated as detail Y in Figure 8 and is described in more detail there.

Figure 7 shows the detail X from Figure 5, i.e. the gill 6a, which is arranged symmetrically upward and downward with respect to a central plane e of the corrugated fin 5. The S-shape of the gill 6a has an approximately sinusoidal profile and is characterized by three sections, namely an incident-flow region 9, a central deflecting region 10 and a flow-off region 11. The inclinations of the individual regions 9, 10, 11 are depicted by straight lines a, b, c. There is a

continuous transition in each case between the sections 9, 10, 11. The incident-flow section 9 forms an incident-flow angle αs with the central plane e, and the flow-off region 11 forms a flow-off angle αs with the central plane e, i.e. the angle between the straight lines c and e. The central cross-sectional region 10, i.e. the deflecting region, forms a deflecting angle βs with the central plane e (angle between the straight lines b and e). The angles αs lie in a range of from 0 to 10 degrees, preferably in a relatively narrow range of from 0 to 5 degrees. The deflecting angle βs lies in a range of from 15 to 35 degrees and preferably in a range of from 20 to 30 degrees. The air flow characterized by an arrow L therefore impinges in the incident-flow region 9 on an extremely small incident-flow angle αs, so that no separations and eddies form on the rear side or suction side of the gill profile. The incident-flow angle αs, which corresponds to the gill angle α in the prior art, changes with increasing flow around the gill 6a up to the value βs and then decreases again to the value αs in the region 11. A separation-free flowing off of the air therefore also takes place. The S-shaped cross section of the gill 6a produces an increased moment of resistance to buckling, i.e. a higher permissible buckling load - in comparison to the known rectangular cross section.

Figure 8 shows the detail Y from Figure 6, i.e. the corrugated fin 7 with gills 8a which are bent twice and have a cross section with a double bend or an approximately Z-shaped profile. The central plane of the corrugated fin 7 is also indicated here with e, i.e. as a reference plane for the individual angles. The cross section of the gill 8a is divided into three sections, namely an incident-flow section 12, a central deflecting section 13 and a flow-off section 14, with all three sections 12, 13, 14 running approximately

rectilinearly and being connected to one another by radii r. The inclinations of the individual sections 12, 13, 14 are marked by straight lines a, b, c and form the incident-flow angle and flow-off angle αz and the deflecting angle βz with the reference plane e. The air flow in turn is illustrated by an arrow L, and it can be seen that the incident-flow angle αz is relatively small, so that hardly any flow-separation phenomena, if any at all, arise on the suction side of the incident-flow section 12 and also of the deflecting section 13. The air flow can therefore bear against the suction side of the gill 8a, which results in a low pressure drop. The incident-flow and flow-off angles αz lie in the range of from 0 to 25 and preferably in the range of from 5 to 15 degrees, and the deflecting angle βz lies in the range of from 15 to 35 degrees and preferably in the range of from 20 to 30 degrees. This Z-shaped profile of the gill 8a also results in an increased moment of resistance to buckling, which is added to the number of gills to form an increased overall moment of resistance to buckling for the entire corrugated fin.

The production of the above-described gills, i.e. both with an S-profile and with a Z-profile, takes place in a similar manner as in the prior art, i.e. by means of "ribbed cutting rollers", which cut the gills out of a planar sheet-metal strip and shape them.